Age of Acquisition, Ageing and Verb Production:

Normative and Experimental Data

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Abstract

Young and old adults were shown pictured or written verbs and asked to name them as quickly as possible. Simultaneous multiple regression was used to investigate which of a set of potential variables predicted naming speed. Age of acquisition was found to be an important predictor of naming speed in both young and old adults, and for both word- and picture-naming. Word frequency predicted picture naming speed only in older adults, and failed to make any significant contribution to word naming speeds for either group of participants. The respective loci and roles of age of acquisition and frequency in lexical processing are discussed in light of these findings.

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Age of acquisition is a variable that has recently enjoyed considerable popularity as a purported determinant of lexical processing ability (e.g., Barry, Hirsh, Johnson & Ellis, 2001; Ellis & Morrison, 1998; Morrison & Ellis, 2000). At the same time, there has been an increasing number of reports in the neuropsychological literature of disorders of speech production that differentially impair performance on noun and verb targets (e.g., Caramazza & Hillis, 1991; Zingeser & Berndt, 1990; Shapiro, Shelton & Caramazza, 2000). The goal of this paper was threefold: first, to examine whether we may extend to verb targets the claim that age of acquisition is one of the primary determinants of lexical processing speed; second, to compile a set of age of acquisition norms for a published set of verb pictures (Fiez & Tranel, 1997); and third, to assess the stability of age of acquisition effects in people of different ages.

Throughout the 1970s there emerged a set of empirical and normative papers that put forward the idea that the speed with which a lexical form could be retrieved for speech production was influenced by the age at which that form had been acquired (e.g., Carroll & White, 1973; Gilhooly & Gilhooly, 1979; Lachman, Shaffer, & Hennrikus, 1974; Whaley, 1978). Interest in the topic was reawakened with the publication in 1992 of the work of Morrison, Ellis, and Quinlan. In this study, age of acquisition and phoneme length were shown to be the only significant predictors of object naming latency. Word frequency did not make a significant contribution to the prediction of object naming latency. In addition, in a reanalysis of Oldfield and Wingfield (1965), the work generally cited as showing the existence of frequency effects in object naming, Morrison et al. found that when age of acquisition was taken into account frequency no longer exerted a significant influence on object naming latencies. Since that time a number of studies have provided data consistent with the hypothesis that age of acquisition is an important determinant of object naming latency (Barry, Morrison, & Ellis, 1997; Cuetos, Ellis & Alvarez, 1999; Ellis & Morrison, 1998; Snodgrass & Yuditsky, 1996; Vitkovitch & Tyrrell, 1995) and other work has shown that age of acquisition also influences word naming speed (Gerhand & Barry, 1998; Morrison & Ellis, 1995; 2000). Thus the hypothesis that age of acquisition influences the speed with which spoken words are produced seems secure.

What seems less certain is whether there is a role for word frequency. Throughout the period in which age of acquisition effects have been demonstrated, opinion has been divided as to whether there are effects of both age of acquisition and frequency or whether frequency effects are simply age of acquisition effects "in disguise". As far as picture naming is concerned, early studies suggested that there were clear age of acquisition effects but little or no role for frequency (e.g., Morrison et al., 1992; Vitkovitch & Tyrell, 1995); more recent studies have tended to conclude that both variables influence naming speed (Barry et al., 1997), although the more important variable seems to be age of acquisition (Ellis & Morrison, 1998; Snodgrass & Yuditsky, 1996). Evidence suggesting equal roles for frequency and age of acquisition in word naming is stronger: while Morrison and Ellis (1995) concluded that word frequency had no role to play in word naming, a growing body of literature reports frequency effects, in addition to age of acquisition effects, on word naming speed (Brysbaert, 1996; Gerhand and Barry, 1998; Morrison & Ellis, 2000).

The reason this issue arouses such interest is that it has implications for theoretical accounts of lexical processing. Traditional accounts of lexical processing embody frequency effects as an essential part of the way the system operates, for example in terms of the threshold levels of lexical units (e.g., Morton, 1979), or the connection strengths between units (Seidenberg & McClelland, 1989). Such accounts make no mention of age of acquisition. But if age of acquisition, and not frequency, is the crucial variable in lexical processing, such accounts are inadequate: a model that cannot help but produce frequency effects is deficient if these effects are found to be spurious. If age of acquisition is the crucial variable, theoretical models need to be sensitive to the order in which items are introduced to the system, rather than their frequency of occurrence. Hence the need to establish firmly the respective roles of both these lexical variables is driven by the fact that, if age of acquisition has a significant role to play in lexical processing, current theoretical accounts are inadequate.

So the issue of whether or not frequency has a role to play in naming speed continues to be debated, and this study addresses that issue. More importantly, this study was designed to explore tasks in which these two effects might be expected to emerge. As a step in this direction we chose to examine the role of lexical variables in predicting the performance of individuals in response to verb targets rather than noun targets (by 'lexical variables', we mean word attributes that have been shown to be important in predicting lexical processing speed). We decided to sample verbs for the following reasons. First, work on neurological patients suggests that the naming of such targets may be differentially affected relative to noun targets following brain injury (e.g., Caramazza & Hillis, 1991; Williamson, Adair, Paymer, & Heilman, 1998; Zingeser & Berndt, 1990), with some even speculating that these differential effects reflect differences in brain localisation for the representations of nouns and verbs (Tranel, Damasio, & Damasio, 1997). These effects persist even when items from the two form classes are matched on word frequency, but there has been no effort to control for age of acquisition levels in any of the studies conducted thus far. Hence it is possible that the patterns previously reported are due to differences in the age at which the particular noun and verb stimuli administered to the patients were acquired rather than due to any processing differences between nouns and verbs per se.

The second reason for an interest in verbs is that work with older adults suggests that they have greater difficulty with word retrieval than do younger adults (e.g., Au, Joung, Nicholas, Obler, Kass, & Albert, 1995; Hodgson & Ellis, 1998; Nicholas, Obler, Albert, & Goodglass, 1985). The experimental studies on this issue have tended to focus on the retrieval of nouns/object names (e.g., Au et al., 1995; Welch, Doineau, Johnson, & King, 1996) or proper names (e.g., Burke, MacKay, Worthley, & Wade, 1991; Maylor, 1990). To our knowledge, only one study, Nicholas et al. (1985), compared verb naming in young and old; they had participants name pictured actions and found that old adults were very much less accurate than young adults. Given the dearth of evidence on this topic, it seems important to attempt to replicate the findings of Nicholas et al. and to extend them by examining action naming latencies as well as accuracy levels. The need for replication seems particularly important in light of the neuropsychological research discussed above suggesting that nouns and verbs are processed/stored differently and thus that they might be differentially affected by the brain changes associated with normal ageing.

A third incentive for studying verb processing is that this area has recently attracted attention in the psycholinguistic domain. Pickering and Frisson (2001) examined the processing of lexically ambiguous or unambiguous verbs in sentence contexts and concluded that verb ambiguity is resolved in a very different way to noun ambiguity. They remarked on the dearth of research into verb processing, and their findings highlight the importance of considering verbs distinctly from nouns. It should not be assumed that any findings from the noun literature may automatically be extended to verbs.

Finally, as outlined above, there are inconsistent results across the word and picture domains. In this study we used the same items in a word-naming and a picture-naming task in order to make direct comparisons between the effects of lexical variables on the naming of words and pictures.

To date no study has assessed the influence of age of acquisition on verb naming capabilities in either intact or brain-injured individuals. In two experiments we set out to explore the role of age of acquisition in the production of verbs. In Experiments 1a and 1b we examined action naming with picture targets. In Experiments 2a and 2b the task was word naming. The participants in Experiments 1a and 2a were undergraduates and in Experiments 1b and 2b they were older adults from the community at large. We expected to find that age of acquisition affected performance in both picture and word naming. Morrison, Hirsh, Chappell and Ellis (in press) recently reported effects of participant age and age of acquisition on object naming for young, old and very old participants, with no interaction between age and age of acquisition, hence in the present study we predicted that the effects would be similar for both age groups. We were also interested to see whether frequency effects emerged as significant, given the mixed pattern of results discussed above. The work of Nicholas et al. (1985) also led us to suspect that younger adults would be more accurate at naming pictured actions relative to older adults.

We used correlational designs in this study, which allowed us to investigate the contributions of a range of independent variables to naming speed and accuracy. Such designs are more commonly used in studies of this type (e.g., Barry et al., 1997; Brown & Watson, 1987; Gilhooly & Logie, 1981; Morrison et al., 1992; Morrison & Ellis, 2000) than are factorial designs, because it is difficult to control all possible contributing variables. In an ideal world, a factorial design would offer a cleaner pattern of results, and we acknowledge that we must be more cautious in interpreting the results of a correlational design than we would be with a factorial design.

Experiments 1a & 1b

Method

Participants. Forty-four undergraduate students took part in Experiment 1a in return for course credit. They ranged in age from 18-27 years, with a mean age of 19.6 years. Thirty older adults took part in Experiment 1b. They ranged in age from 65-87 years, with a mean age of 75.5 years. They reported they were in good health and had not to their knowledge suffered any brain injury such as stroke. The average age at which the older participants left education was 14.9 years. Seventeen of the older participants were long-sighted and ten were short-sighted. These twenty-seven wore corrective lenses during the experiment. Payment to the older participants was £3 plus any travel expenses incurred.

Materials & Apparatus. The stimuli were digitised photographs adapted from Fiez and Tranel (1997), who published a large set of pictures representing verbs. They devised a set of 280 photographs which can be used to elicit action names (verbs). Two hundred and ten of these are single picture targets designed to elicit the gerundial (*-ing*) form and the remainder comprise pairs of pictures designed to elicit the past tense form. The items were selected to vary along several syntactic and semantic dimensions. By way of example, their items vary in terms of the argument structure required by the verb, that is, transitive/ditransitive (e.g., arrange, loan), intransitive (e.g., smile, dine); in terms of semantic category, for example, verbs of motion, perception or creation; and in terms of the type of agent performing the action (e.g., person or animal). Fiez and Tranel collected normative data on visual complexity (the amount of detail or intricacy in a picture), familiarity (the degree to which one comes into contact with or thinks about an object) and image agreement (the extent to which a picture matched one's mental representation of that concept) for all 280 items. They also obtained written naming responses for each of the items from which they calculated two measures of name agreement: percentage of participants giving the target response and the information *H* statistic, computed using a formula which includes the number of different names given to an image and the proportion of participants giving each name. The authors argued the latter is a better measure of name agreement as it carries information about the distribution of responses. Fiez and Tranel did not, however, provide age of acquisition ratings for their stimuli and thus one goal of the present study was to provide normative data on age of acquisition that may be useful to researchers who intend to utilise the Fiez and Tranel materials. Moreover, their name agreement data are based on the responses of undergraduate students. If the Fiez and Tranel pictures are to be useful in the context of brain injury, it is important to have name agreement data on the items from a sample drawn from the population most at risk for brain injury — older adults.

Fiez and Tranel (1997) reported low name agreement for many of their items, so 125 items with high name agreement were selected. Six pilot participants then named these digitised photographs. Fifteen items were removed because they were named correctly by fewer than three of the six participants. In addition the target response was changed for five of the items after all of the pilot participants produced this alternative response when presented with the item. Specifically ERASING, MAILING, SLEDDING, VACUUMING and WEIGHTING were changed to RUBBING, POSTING, SLEDGING, HOOVERING and WEIGHING respectively. This left 110 items.

The digitized photographs were in black and white and measured 19.6 cm in length and 13.4 cm in height. They were presented against a white background in the centre of the screen of a Macintosh IIcx using SuperLab 1.68.

Age of acquisition values were obtained for the Fiez and Tranel (1997) stimuli by asking students to rate on a scale of 1-7 the age at which they first learnt a word in either spoken or written form. Morrison, Chappell and Ellis (1997) showed that such subjective ratings correlated highly with objective measures derived from data on children's vocabulary knowledge ($r = .76$), and concluded that rated age of acquisition is a valid and reliable reflection of real word learning age. The age of acquisition scale used here was taken from Gilhooly and Logie (1980), where 1 = word learnt at age 2 or below, 2 = 3-4 years, 3 = 5-6 years, 4 = 7-8 years, 5 = 9-10 years, 6 = 11-12 years, and 7 = word learnt at age 13 or above. It was stressed to participants that all the words presented for rating were verbs. The words were presented in the centre of the screen (black letters on a white background), and participants were required to enter the appropriate number from the scale provided, and then press the space bar to start the next trial. Presentation order was randomised for each participant. Thirty undergraduate students participated in the ratings study in return for course credit. Age of acquisition ratings for all 267 unique names in Fiez and Tranel (1997) may be found in Appendix A.

Procedure. Participants were instructed that they would be presented with a series of digitised photographs each depicting a different action and were told to name aloud each action using a single word. Four practice trials were used to demonstrate the experimental procedure and calibrate the voice key. The order of stimulus presentation was randomised for each participant. Each stimulus item was preceded by a prompt question appropriate to the picture, for example, "What is this person doing?" (See Appendix A for a full list of the question prompts). This question prompt appeared for 2000 ms. At the end of this interval the target stimulus appeared. It remained on the screen until the participant responded verbally after which time the experimenter initiated a 1000 ms inter-trial interval. Vocal responses activated a microphone attached to the headset worn by participants. This triggered a hardware voice key connected by a custom response box to an NB-DIO data collection board that timed response latencies. The participants' naming responses, along with any equipment difficulties, were recorded by the experimenter.

Results

Table 1 provides mean RTs for correct responses. Failures to produce the correct name are given as a percentage of the total number of items, as are responses discarded due to equipment failures (premature or delayed voice key triggerings). The name agreement values for Experiments 1a and 1b may be found in Appendix A.

Analyses of Naming Latencies. Errors were defined as any response other than the target word. Items with high error rates (>25%) were removed from the analyses. The difference in naming latencies between the two age groups was significant, t_1 (72) = -3.60, p <.001, t_2 (109) = -8.20, p <.0001, indicating that young adults (Experiment 1a) responded more quickly than older adults (Experiment 1b).

The relationship between naming latencies and a set of predictor variables was examined. Of primary interest was the relationship between rated age of acquisition and naming latencies. As discussed in the Introduction we believe this to be the first study to assess the influence of age of acquisition on verb naming. In addition to age of acquisition a variety of other variables have been argued to affect naming performance. Familiarity, visual complexity and image agreement values were taken from Fiez and Tranel (1997). Three measures of word length were included — number of letters, number of phonemes and number of syllables, in order to establish which measure best fitted the data. A number of different measures of word frequency appear in the literature. We selected a British English corpus (the CELEX Database, Baayen, Piepenbrock & Gulikers, 1995) for our analyses. Values for lemma frequency, base word form (e.g., box) frequency and the present participle (e.g., BOXING) frequency were extracted. Thus three measures of word frequency were utilised. We calculated name agreement separately for each experiment as well as overall agreement across experiments with the *H* Statistic following the equation laid out in Fiez and Tranel (1997)[1]. Finally, we included two variables to account for initial phoneme differences. As experimenters know all too well, words with different initial phonemes may take more or less time to trigger the voice key (Treiman, Mullenix, Bijeljac-Babic & Richmond-Welty, 1995). For example, Morrison and Ellis (2000) reported that, among other things, faster RTs in a word naming task were associated with initial voiced sounds (as in *moon*), while slower RTs were associated with initial velar sounds (as in *gun*). Morrison and Ellis included a set of 12 initial phoneme dummy variables in their analysis, but, due to the limited number of cases and the number of independent variables we wished to include here, we could not consider the inclusion of such a large number of independent variables to code for initial phoneme. Instead, we considered the most crucial features of phonemes that might affect detection speed to be voicing and frication. Object labels which began with voiced sounds (e.g., *bending*, *lifting*, *walking*) were denoted with the dummy variable 'voicing'; labels which began with fricative or affricative sounds (e.g., *feeding*, *hurdling*, *swimming*) were denoted with the dummy variable 'frication'.

Table 2 displays the correlation matrix for the 13 predictors. This shows that age of acquisition correlates highly with familiarity, visual complexity, word length, *H*, and with all of the word frequency measures.

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[1] $$H = \sum_{i=1}^{k} p_i \log_2 1/p_i$$

Where k is the number of different names given to each picture, and p_i is the proportion of participants giving each name.

Table 3 shows the relationship between the predictors and naming latency for the young adults in Experiment 1a and the older adults in Experiment 1b. In both groups age of acquisition correlated highly with naming latency (Young = .43; Old = .47). There were also high correlations between latency and the *H* name agreement statistics (Young = .64; Old = .61). Also of note is the high correlation between naming latency and visual complexity in the older group (.28).

For each experiment a multiple regression was performed using mean naming latency as the dependent variable. Where there was more than one measure of a particular variable (i.e., word frequency and word length), the measure that correlated most highly with naming latency across both groups was used; this provided the best fit to the naming data. Nine independent variables were included: rated AoA (see Appendix A); familiarity, visual complexity, image agreement (all taken from Fiez & Tranel), number of syllables; log (1+*x*) word frequency of the *-ing* form (Baayen et al., 1995); and the *H* name agreement statistic (calculated separately for each experiment/age group); plus the two initial phoneme dummy variables. The results of the multiple regressions on naming latencies for both Experiment 1a (young adults) and Experiment 1b (older adults) are given in Table 4. Both regression equations were significant, $R^2_1 = .44$, $F_1(9,100) = 8.82$, $p < .0001$; $R^2_2 = .50$, $F_2(9,100) = 11.0$, $p < .0001$. Age of acquisition and *H* name agreement were significant predictors in both equations. Visual complexity and log word frequency of the *-ing* form were significant predictors of performance for older adults (Experiment 1b). None of the other measures made significant contributions to latency.

<u>Analyses of Naming Errors</u>. Deloche et al. (1996) found that name agreement for object names decreased significantly with age (.96 under 40 years of age; .92 above 60 years). This was also true in the present study: mean name agreement among the young adults was .88, mean name

agreement among the older adults was .78, t_1 (72) = 8.97, p <.0001, t_2 (109) = 6.13, p<.0001. In other words the participants in Experiment 1b (older adults) made more errors than the participants in Experiment 1a (young adults). In addition to making more errors, older adults also made a wider variety of errors, reflected in a significantly higher mean *H* statistic: mean *H* statistic for the young adults was .56, mean *H* statistic for the older adults was .89, t_2 (109) = 6.08, p<.0001.

Table 3 shows the relationship between the predictors and error rates for Experiments 1a and 1b. High correlations between age of acquisition, number of phonemes and the various word frequency measures were obtained. Regression analyses were conducted on the proportion of errors made by participants. The measure of word length used here was number of phonemes. The *H* name agreement statistic was not utilised as the number of errors made is used to calculate this statistic; nor were the initial phoneme variables included here as they should not influence error rate and they did not play a significant role in determining RT. All other independent variables remained the same. The results of the regression analyses on number of errors for both Experiment 1a (young adults) and Experiment 1b (older adults) are given in Table 5. Both regression equations were significant, R^2_a = .20, $F_a(6,103)$ = 4.15, p < .001; R^2_b = .29, $F_b(6,103)$ = 6.85, p < .0001. There was a significant effect of age of acquisition in both groups. The effect of word frequency was significant in Experiment 1b (older adults) and marginally significant in Experiment 1a. In Experiment 1b (older adults) there was also a significant effects of image agreement. This effect approached significance in Experiment 1a.

Discussion

In Experiments 1a and 1b we have demonstrated an effect of age of acquisition on verb-picture naming latencies. Age of acquisition also influenced error rates. As far as we are aware this is the first demonstration of an age of acquisition effect on the naming of pictured actions. Finding an age of acquisition effect in verb naming increases the generality of the claim that age of acquisition is a crucial determinant of picture naming speed by showing that this effect is not limited to object/noun stimuli. In addition, although the older participants in Experiment 1b named the pictured actions more slowly and were more error prone than the young participants in Experiment 1a, the performance of both groups was affected by age of acquisition.

Name agreement (here operationalised as the *H* statistic) was also a strong predictor of naming latency for both groups. This is consistent with the results of Barry et al.'s (1997) study of object naming as well as the results of Vitkovitch and Tyrrell (1995), who also reported significant age of acquisition effects. This finding is also in line with reports of codability effects on object recognition (e.g., Gilhooly & Gilhooly, 1979; Griffin, 2001; Lachman, 1973; Lachman & Lachman, 1980; Lachman et al., 1974). Codability is usually defined as the number of alternative names given to an object and so is slightly different to the measure we used here. In addition, the analyses comparing name agreement across the two experiments showed that there was a significant decrease in the level of agreement with age, both in terms of the number of participants producing the dominant name and in terms of the number of non-dominant responses produced (reflected in the *H* statistic).

In Experiment 1b we also saw an effect of word frequency on the naming latencies of the older adults. Significant frequency effects were also apparent in the error analyses for Experiment 1b. These results are consistent with some findings reported for young participants (Barry et al., 1997; Ellis & Morrison, 1998; Snodgrass & Yuditsky, 1996) and suggest that frequency effects are sometimes observed in picture naming experiments that also include age of acquisition as a predictor variable. The fact that frequency effects were only apparent in the older participants suggests that we should treat this finding with caution and bear in mind that it did not apply to all participants in the present study. In our view the present findings do not enhance claims of the generality of the frequency effect in picture naming. Like Morrison et al. (1992) and Vitkovitch and Tyrell (1995), we found no frequency effect on the picture naming latencies of young people; the advantage of the present task over these earlier studies is that we used a large set of items and a better measure of frequency (both these studies used the rather dated North-American Kucera & Francis (1967) frequency corpus).

In a review of studies of picture naming accuracy in older adults, Goulet, Ska and Kahn (1994) suggested that visuo-spatial deficits may have a role to play in explaining the decline in naming ability typically seen in old age. Consistent with this suggestion, we found effects of visual complexity in the analysis of naming latencies from Experiment 1b. There was also an effect of image agreement in the analysis of error rates from Experiment 1b. This finding is unsurprising: pictures that do not agree with participants' mental images of given objects are more likely to be named erroneously than those pictures that closely resemble participants' mental images.

In addition to finding further evidence for the role of age of acquisition in lexical access we also achieved our goal of providing name agreement data from a sample of older adults as well as age of acquisition norms for the Fiez and Tranel (1997) stimuli. Both pieces of normative data enhance the usefulness of the Fiez and Tranel stimuli.

Experiments 2a & 2b

In Experiments 2a and 2b we examined reaction times to the written names of the Fiez and Tranel stimuli. There are many reports of age of acquisition effects in the word naming task using noun stimuli (Brown &

Watson, 1987; Brysbaert, 1996; Brysbaert, Lange & Van Wijnendaele, 2000; Coltheart, Laxon & Keating, 1988; Gerhand & Barry, 1998; Gilhooly & Logie, 1981; Morrison & Ellis, 1995; 2000). We therefore hypothesised that age of acquisition would also predict word naming latencies to verbs in both young and older participants. We also expected to see frequency effects, given the wide reporting of frequency effects in word naming (Brysbaert, 1996; Gerhand & Barry, 1998; Morrison & Ellis, 2000). Third, we expected that older participants in Experiment 2b would respond more slowly than young participants in Experiment 2a, given the strong trend for this finding in the literature on ageing and word naming (Allen, Madden, Cerella, Jerge, & Betts, 1994; Balota & Duchek, 1988; Balota & Ferraro, 1993; Hartley, 1988; Nebes, Boller, & Holland, 1986; Nebes, Brady, & Huff, 1989).

Method

Participants. Thirty undergraduate students participated in Experiment 2a in return for course credit. Their ages ranged from 18-24 years, with a mean age of 21.2 years. Thirty older volunteers participated in Experiment 2b. Their ages ranged from 65-83 years, with a mean age of 74.2 years. Again, they reported they were in good health and had not to their knowledge suffered any brain injury such as stroke. Nineteen older participants took part in both Experiment 1b and Experiment 2b; however two months separated the testing sessions. All of the older participants were paid £2 plus travel expenses for taking part.

Materials & Apparatus. The written names of all of the Fiez and Tranel (1997) photographs formed the stimuli for Experiments 2a and 2b. Fiez and Tranel provided more than one picture for 12 of their verbs, so the original set of 280 pictures was reduced to 268 words (see Appendix A). In addition, due to differences in British and North American English, the word ERASING was replaced with the word RUBBING. As RUBBING was already part of the stimulus set (as the name of a different action) there was no need to present it twice. This left 267 items.

The stimulus words were 6 mm tall and ranged from 20 to 65 mm in length. They were displayed in uppercase, 24-point Geneva font. They were presented, black on a white background, in the centre of the screen of a Macintosh IIcx using SuperLab 1.68.

Procedure. Participants were instructed that they would be presented with a series of single words and that they should name each word as quickly as possible. Ten practice trials were used to demonstrate the experimental procedure and calibrate the voice key. At the start of each trial a fixation cross appeared in the centre of the screen for 500 ms. This cross was replaced by the target word. Responses were recorded in the same manner as the previous experiments and initiated a 1000 ms intertrial interval. Presentation order was randomised for every participant.

Results

Given that 19 of the older adults who participated in Experiment 2b had also participated in Experiment 1b, word naming latency for these older participants was compared with word naming latency for the 11 older participants who took part only in Experiment 2b. The participants who had done both experiments were actually marginally slower overall than those who had only participated in Experiment 2b (mean RTs of 530 ms and 516 ms, respectively); this difference was significant by items, t_2 (266) = 6.00, $p < .0001$, though not by subjects, t_1 (28) = .60, $p > .50$. This effect is in the opposite direction one would expect if participants had been primed by participation in the first experiment.

Table 6 summarises naming performance in Experiments 2a and 2b. The older participants in Experiment 2b responded more slowly than did the young participants in Experiment 2a; this difference in naming latencies across the two experiments was highly significant, t_1 (58) = -6.67, p <.0001, t_2 (266) = -59.03, p <.0001. Due to the low error rates, naming speed was the only dependent variable to undergo further analysis. Word imageability was added to the set of predictor variables here because Strain, Patterson and Seidenberg (1995) reported imageability effects in word naming, such that words rated as high in imageability were named more easily than words rated low in imageability. We did not include imageability in the analyses of Experiments 1a and 1b as the pictures have a restricted imageability range: picturable objects are, by their very nature, highly imageable, therefore the items chosen for the picture naming subset are at the high end of the imageability scale. Regression analysis requires that independent variables be reasonably well distributed, and this is not the case for imageability in the picture naming set. However, for the words, the imageability range was broader, allowing the inclusion of the variable in this case. An independent group of 30 participants rated the words on a scale from 1-7, where 1 = 'arouses little or no mental image' and 7 = 'arouses a mental image very quickly and easily'. Three of the variables included in the analyses of Experiments 1a and 1b were not included here as they are specific to picture naming (image agreement, visual complexity and the *H* name agreement statistic); hence, with the inclusion of imageability, the number of independent variables in the correlational analyses was reduced to seven.

Table 7 shows the intercorrelations between the ten predictor variables. Note that, while the correlations are very similar to those reported in Table 2, they are not identical because items used in Experiments 2a and 2b were a superset of those used in Experiments 1a and 1b. Also note the high correlations between imageability and age of acquisition and measures of word length and frequency. Table 8 contains correlations between the dependent variable and each of the predictor variables in Experiments 2a and

2b, and shows that for both experiments age of acquisition had the highest simple correlation with word naming latency.

A multiple regression was conducted on these data with word naming latency as the dependent variable. The measure of word frequency used was log word frequency of the *-ing* form in order to provide consistency with Experiments 1 and 2. The word length measure used was number of phonemes.[2] The remaining independent variables were age of acquisition, imageability, familiarity, and two dummy variables coding initial phoneme. The regression equations for both experiments were significant $R^2_a = .15$, $F_a(7,259) = 6.42$, $p < .0001$; $R^2_b = .23$, $F_b(7,259) = 11.24$, $p < .0001$; the results are shown in Table 9. Two variables had a significant effect in experiments 2a and 2b: age of acquisition and voicing, with early words being named more quickly than late words; curiously, the direction of the voicing effect indicates that words with voiced initial phonemes were named more *slowly* than words with unvoiced initial phonemes. In addition, there was an effect of frication in Experiment 2a (young adults), such that words with initial phonemes that were fricatives were named more slowly than other words; number of phonemes was marginally significant for Experiment 2a.

Discussion

Participants' responses to early-acquired written verbs were produced significantly more quickly than their responses to late-acquired written verbs. This was true both for the young adults in Experiment 2a and the older adults in Experiment 2b. Familiarity, word frequency, length and imageability all failed to reach significance in both experiments.

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[2] Number of phonemes was chosen as the word length measure for inclusion in the regression analyses because it was highly correlated with the dependent variable. The pattern of results was very similar when number of letters, rather than number of phonemes, was the measure of word length used, however only AoA reached conventional significance levels in the regression analyses for both Experiments 2a and 2b.

These findings are consistent with the work of Brown and Watson (1987), Gilhooly and Logie (1981) and Morrison and Ellis (1995), who also found effects of age of acquisition on word naming latencies but no effect of word frequency. They are at variance with other studies which reported effects of both age of acquisition and word frequency on word naming latency (Brysbaert, 1996; Gerhand & Barry, 1998; Morrison & Ellis, 2000). They also contrast with our results with older participants (Experiment 1b) in verb-picture naming. This result adds to the confused picture of the role of frequency in naming, and we deal with this issue further in the General Discussion.

The effects of initial phonemes on word naming speed are not surprising; they have been reported in earlier studies (e.g., Morrison & Ellis, 2000; Treiman et al., 1995). What is surprising is the direction of the finding for voicing: words with voiced initial phonemes were *slower* to name than words with unvoiced initial phonemes. This effect was small in the young adults but marked in the older adults. As it contrasts with the findings of Morrison and Ellis (2000) and Treiman et al. (1995) we felt that it was worth noting; however we do not feel able to offer an explanation.

ANOVA Analysis of Picture and Word Naming Data

In order to compare slowing of older adults' responses in picture- and word-naming, we conducted an ANOVA analysis on the combined data from Experiments 1 and 2, allowing us to examine a possible interaction between the factors of age and task. This technique was used by Feyereisen, Demaeght and Samson (1998) in order to test the merits of various theories of age-related slowing. They reported a general trend towards a larger effect of age-related slowing in picture- than in word-naming; in other words, when the responses of the two groups are compared there are larger age effects in picture naming.

This appears to be the case in the present experiments also, with older adults only 94 ms slower at word naming (Table 6), but 248 msec slower at picture naming than young participants (Table 1). ANOVA analysis on these data showed significant effects of task (picture/word), $F_1(1,130) = 750.31$, MS = 25039306, $p<.0001$, $F_2(1,109) = 827.9$, MS = 96836891, $p<.0001$, and group (young/old), $F_1(1,130) = 21.92$, MS = 731468, $p<.0001$, F_2 (1,109) = 172.7, MS = 3585181, $p<.0001$; and an interaction between task and group that failed to reach significance by participants, $F_1(1,130) = 2.96$, MS = 98777, $p > .05$, but did reach significance by items, $F_2(1,109) = 40.68$, MS = 865161, $p<.0001$. This interaction, although not reliable, hints that the older participants may have been especially slow on the picture naming task, which supports Feyereisen et al.'s finding. However, given that older adults' reaction times are much slower than younger adults, these results should perhaps not be taken at face value. Cohen (1988) suggested computing point biserial correlations from the F value in order to examine effect size[3]; when this was done for the present data the value was low ($r_{pb} = .15$), indicating a small effect size.

Perhaps a more appropriate way to compare the data from young and old is to consider the reaction times of the young and old participants for each item as proportions (old/young), as Birren, Woods and Williams (1980) did; when this was done, the differences became very much less marked, with a mean for word naming of .22 and a mean for picture naming of .21. When these data were analysed there was found to be no significant effect of task ($F < 1$), suggesting that the old were not differentially bad at picture naming in comparison to the young. This result suggests that age-related changes in lexical processing are the same for picture naming and word naming.

Although this finding contrasts with that of Feyereisen et al. (1998), it does not preclude the possibility that there are certain task-specific factors

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[3] The formula is as follows:
$F(x, y) = z$
$r_{pb} = sqr(z/(y + z))$

which partly account for the slowing seen in older adults' picture naming. We noted that visual complexity exerted a significant effect on picture naming for older adults but not for young adults. This suggests older adults are particularly disadvantaged when presented with complex stimuli. In order to explore this further we divided the pictures into two groups, high and low complexity, using a median split and analysed the reaction times, with group (young/old) as the within-subjects factor. We found, as above, a main effect of group on reaction time ($F [1,108] = 87.4$, $MS = 3404882$, $p < .0001$) and a marginal effect of visual complexity ($F [1,108] = 3.51$, $MS = 787112$, $p = .06$). But, importantly, there was a highly significant interaction between group and complexity ($F [1,108] = 8.23$, $MS = 322884$, $p < .01$), such that the complexity effect was greater for the old adults than for the young. This indicates that the old participants were particularly affected by the task-specific factor of visual complexity. Thus we would conclude that the differences in age-related changes observed in these naming tasks may owe less to differences at a *lexical* level than to non-lexical differences between the two tasks.

General Discussion

In the two experiments described here we aimed to determine whether the age of acquisition effects seen in experiments on word and picture naming with noun stimuli would generalise to experiments involving verbs as stimuli. In both experiments we found that participants' naming latencies were indeed influenced by age of acquisition, such that early-acquired verbs were produced more quickly than later-acquired verbs.

The findings with regard to word frequency were more equivocal. We found a frequency effect only for picture naming latency in older adults (Experiment 1b). Thus word frequency appears to be a less potent predictor than age of acquisition in verb as well as in noun naming. We are careful in drawing this conclusion in view of the less-than-optimal nature of the correlational designs used in the present study, although we are confident that our design was as thorough as possible. This is of some import as the studies of action and object naming in neurological patients have attempted to equate items from the two form classes on word frequency but have made no attempt to control for age of acquisition. The results of Experiment 1b suggest that it is important to control for both variables if the comparisons between nouns and verbs are to be valid and reliable.

Across the two experiments we found that the reaction times of young adults were faster than those of older adults. This is consistent with findings from the noun naming literature, which suggest that older adults are slower than young adults at naming both pictures (Mitchell, 1989; Morrison et al., in press; Thomas, Fozard, & Waugh, 1977) and words (Allen, Madden, Cerella, Jerge, & Betts, 1994; Balota & Duchek, 1988; Balota & Ferraro, 1993; Hartley, 1988; Nebes, Boller, & Holland, 1986; Nebes, Brady & Huff, 1989). We also found that young adults were more accurate at naming pictured actions. This latter finding is consistent with the single study in the literature comparing action naming accuracy across age groups (Nicholas et al., 1985) as well as with the results of Deloche et al. (1996) for object naming. As far as we are aware this is the first report of an effect of participant age on reaction times to written and pictured verbs.

In contrast to recent findings in the psycholinguistic literature (Pickering & Frisson, 2001), these results fit rather well on the whole with findings from research on noun naming, with the same variables exerting an influence in similar ways on speed and accuracy. For reasons of direct comparison, there are other features of verbs which we did not include in our analyses but which may also be important in speed of processing: specifically, the number of arguments (or noun phrases) a verb takes and its semantic complexity. However, we would argue that, although such factors may be important in sentence-processing situations, where the verb is presented in a semantic context, they would be of little help in retrieving the spoken name for verbs in single-word naming situations. Related to this, in analyses of noun naming, we have failed to find effects of the key semantic attributes prototypicality (Morrison et al., 1992) and imageability (Ellis & Morrison, 1998; Morrison & Ellis, 2000); nor did we find an effect of imageability in Experiment 2 here. Hence it seems that such semantic-attribute variables do not generally emerge as significant in single-word naming tasks.

Frequency, age of acquisition and the mental lexicon

Our results raise some interesting questions with regard to the respective roles of age of acquisition and frequency in lexical processing. Frequency emerged as significant only for picture naming in older adults (Experiment 1b). As such, the generality of frequency effects is seriously undermined. Why frequency should become important in later life is unclear, although we discuss one possibility in the following section.

A recent debate in the literature has been concerned with whether word naming latency is predicted by both age of acquisition and frequency (e.g., Gerhand & Barry, 1998), or solely by age of acquisition (e.g., Morrison & Ellis, 1995). Our present findings (Experiments 2a and 2b) favour the latter hypothesis: although the simple correlations between word naming speed and the various measures of frequency were moderately high ($r \approx .20$, see Table 8), frequency failed to make any impact in the multiple regression analyses (Table 9). Owing to the correlation between frequency and age of acquisition ($r \approx .50$, Table 7) there would have been a great deal of overlap in the portion of the variance in naming latencies accounted for by these two variables, hence it is only when both variables are present in a regression analysis that one is able to determine which of the two makes the larger unique (independent) contribution to the prediction of naming latencies. Previous findings (e.g., Brown & Watson, 1987) and the present results paint a consistent picture: when the variance accounted for by age of acquisition is partialled out of the total variance, frequency makes little or no unique contribution to the prediction of naming latencies. Hence the conclusion we draw from our present findings is that age of acquisition, but not frequency, plays a role in word naming latency.

That being the case, how and where does age of acquisition exert its influence in the lexical processing system? Most accounts of age of acquisition have favoured an output locus, such that age of acquisition influences word retrieval and production, but not word recognition (e.g., Barry et al., 1997; Brown & Watson, 1987; Morrison et al, 1992). Perhaps not surprisingly, given the overlap between frequency and age of acquisition, there is a long-established view that frequency effects, too, are likely to have their locus at the level of word output (e.g., McRae, Jared & Seidenberg, 1990; Wingfield, 1968; but see Balota & Chumbley, 1984, for an alternative viewpoint). Jescheniak and Levelt (1994) reported a series of experiments aimed at localising the frequency effect in word naming with respect to a detailed model of speech production (Levelt, 1989), and concluded that it arose at the level of word-form retrieval, that is, a late stage in word retrieval in which phonological forms are specified, beyond the lemma level (at which syntactic information is specified). Jescheniak and Levelt did not include or control for age of acquisition, and it seems entirely possible that much or all of their apparent frequency effect may have been an age of acquisition effect. More recently, Levelt, Roelofs & Meyer (1999) acknowledged that there was strong evidence to indicate that age of acquisition is crucial in naming, and concluded that both age of acquisition and frequency influence word retrieval at the word form level. Adopting this framework, our results – clear age of acquisition effects in both word and picture naming for young and old participants - would be consistent with a locus for age of acquisition at the level of accessing word forms.

However, some researchers have argued recently that this view is incompatible with the finding of age of acquisition effects in recognition tasks like lexical decision, and a view now gaining considerable attention favours an influence of age of acquisition at many levels of processing (Brysbaert, Van Wijnendaele & De Deyne, 2000; Moore & Valentine, 1999). This is compatible with recent connectionist modelling of age of acquisition effects by Ellis and Lambon-Ralph (2000). They demonstrated that such effects can be modelled in backpropagation networks, and suggested that "age of acquisition effects should occur whenever networks with certain basic properties are required to learn and represent associations between input and output patterns in a cumulative and interleaved manner" (Ellis & Lambon-Ralph, p. 1120). The strong suggestion here is that age of acquisition effects should be widespread not just for lexical information, but in many psychological domains. Connectionist models of age of acquisition embody age of acquisition in the connection strengths between units at different levels. By this account, age of acquisition would be a feature of the weights of connections between representational levels, rather than the representations themselves.

The present study was confined to examining word production, where clear age of acquisition effects were found for all participants. As such they are compatible with the view that age of acquisition exerts its influence at the word-form level in the manner suggested by Levelt et al. (1999), but they do not rule out the possibility recently put forward that the effects may be much more widespread than this.

Implications for cognitive slowing

Finally, these results are informative with respect to theories of age-related cognitive slowing. The present experiments, along with a substantial body of literature (e.g., Allen et al., 1994; Au et al., 1995; Balota & Duchek, 1988; Balota & Ferraro, 1993; Feyereisen et al., 1998; Hartley, 1988; Mitchell, 1989; Morrison et al., in press; Nebes et al., 1986; Nebes et al., 1989; Thomas et al., 1977), indicate that retrieval of lexical items takes longer when one is old than when one is young. There is considerable debate in the literature as to whether the effects of ageing observed in tasks such as these are due to generalised slowing (e.g., Hale & Myerson, 1995; Salthouse, 1996), or to task-specific factors which affect naming tasks (e.g., Amrhein, 1995), with current opinion favouring generalised slowing. The data from Experiment 1b suggest that visual recognition of a pictured action is slowed in older adults, as evidenced by the fact that an image's visual complexity has a strong influence on RT, with more complex pictures being responded to more slowly than simple pictures. So, is the slowing we observe in older adults mainly due to recognition deficits, or is there also a problem in retrieving the appropriate lexical item?

The results of the analysis reported here indicated effects of both age and stimulus modality (pictures versus words) on naming performance, but there was no clear evidence of an interaction between the two variables. In our view, this lends support to the general slowing hypothesis. In addition, however, the finding that older adults were differentially badly affected by highly complex stimuli in the picture naming task suggests that there were task-specific factors at play. So, in addition to being affected by lexical factors such as age of acquisition and frequency, picture-naming in older adults is affected by the problems older people experience in perceiving the pictured actions. However, Park (2000) pointed out that complex tasks will yield larger age differences than will simple tasks, but that this is entirely compatible with the global slowing hypothesis. Hence an interaction between task and age, as found here, does not necessarily challenge the view that ageing involves generealised slowing of cognitive processes.

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Appendix A

Rated Age of Acquisition Values for the Stimuli Used in Experiments 1 and 2; the Overall *H* Statistic (a measure of name agreement) from Experiments 1a & 1b, Prompts Used in Experiments 1a & 1b, and Name Agreement values from Experiments 1a & 1b.

* denotes items used in Experiment 1.

Item	AOA	Overall H	Prompt Expt 1a and 1b	Expt 1a Young Name Agreement (%)	Expt 1b Old Name Agreement (%)
absorbing	5.2				
addressing	3.9				
arranging*	4.39	0.7	7	93.18	84.38
assembling	5.07				
baking	3				
balancing*	3.83	0.95	5	93.18	68.75
bending*	2.8	0.3	6	93.18	100
biting	1.9				
blocking	2.53				
blowing*	2.13	0.1	5	100	96.88
bouncing*	2.37	1.1	7	93.18	71.88
bowing	2.73				
boxing*	3.3	0.62	4	84.09	90.63
branding	4.5				
breaking	2.6				
brushing*	2.47	0.93	7	79.55	68.75
bucking	4.73				
burying	3.7				
canoeing	4.1				
carrying*	2.63	0.64	6	90.91	87.5
carving	4.37				
catching	2.33				
chewing	2.34				
chipping	2.37				
chirping	4				
choking	3.67				
chopping	3.2				
clapping*	1.77	0.24	5	95.45	96.88
climbing*	2.43	0.18	5	97.73	96.88
closing	2.27				
coiling	4.47				
colouring	2.13				
conducting	5.17				
connecting	4.57				
covering	3.03				
cracking	3.41				
crashing	2.9				
crawling*	2.1	0.1	5	97.73	100
crumble	3.9				

crumpling*	4.46	2.69	6	31.82	28.13
crushing	3.57				
curling	3.3				
curtsying	4.4				
cutting*	2.1	0	6	100	100
dealing*	4.13	1.08	7	84.09	62.5
developing	4.83				
dialing*	3.4	1.63	7	65.91	50
digging	2.5				
directing	4.4				
dissolving	5.27				
diving	3.38				
dragging*	3.37	1.43	6	63.64	78.13
drawing	2.07				
dressing	2				
drinking	1.53				
dripping	2.97				
dropping	2.27				
ducking	1.77				
dunking	4.37				
dusting	3.03				
eating*	1.43	0.52	6	90.91	90.63
emptying	2.23				
enlarging	4.8				
erupting	5.17				
extinguishing	5.6				
fainting*	4.47	2.13	5	54.55	50
falling	1.7				
feeding*	2.03	0.1	3	97.73	100
fencing	3.07				
fighting	2.43				
filling	2.73				
fishing*	2.48	0.1	5	97.73	100
fixing	3.03				
flexing*	5.14	2.13	5	65.91	40.63
flipping	4.07				
flowing	3.73				
flying*	2.07	0.34	2	100	87.5
folding*	2.9	1.51	6	95.45	43.75
following	2.73				
framing	3.7				
fraying	5.17				
freezing	3.53				
frowning	3.57				
frying	3.47				
galloping	3.93				
gesturing	5.43				
giving	1.9				
grabbing	2.63				
grating*	4	0.78	6	100	71.88
grazing	3.77				
grinding	4.37				
growing	2.47				

hammering	2.97				
hanging*	3.23	0.48	6	93.18	93.75
harvesting	4.03				
hatching	3.8				
herding	3.93				
hiding	1.9				
hiking	4.6				
hobbling	4.87				
holding	2.4				
hoovering*	2.8	0.86	7	95.45	68.75
hugging	1.57				
hurdling*	4.53	1.34	5	75	46.88
interviewing	5.23				
ironing	3.23				
juggling*	3.93	0.28	5	97.73	93.75
jumping	1.97				
kicking*	1.93	0.1	6	100	96.88
kissing*	1.77	0.18	3	100	93.75
kneeling*	2.93	0	5	100	100
knitting*	3.33	0.28	5	97.73	93.75
knocking*	2.69	1.05	5	70.45	93.75
labeling	3.87				
laminating	6.43				
laughing	1.93				
leading	3.37				
leaning*	3.66	0.1	5	100	96.88
licking*	2.33	0.34	6	95.45	93.75
lifting*	2.73	0.38	6	95.45	93.75
lighting	2.17				
listening*	2.03	0.72	5	88.64	87.5
loading*	3.7	1.35	6	86.36	62.5
looking	1.63				
lowering	3.63				
marching*	2.9	1.42	5	77.27	62.5
measuring*	4.13	0.63	6	90.91	84.38
meditating*	6.27	1.93	5	72.73	40.63
melting	3.4				
milking*	2.57	0	5	100	100
mixing	2.83				
mounting	4.57				
nailing	2.83				
nurseing	2.27				
offering	3.53				
opening*	1.83	0	6	100	100
packing*	3.23	1.37	5	90.91	59.38
painting*	1.87	1.44	5	50	37.5
parachuting*	4.63	1.22	5	77.27	87.5
passing	2.77				
peeking	2.8				
peeling	3.2				
perching	4.33				
petting	2				
picking*	2.57	0.78	6	93.18	81.25

pinching*	2.8	0.45	3	97.73	87.5
planting	2.5				
playing*	1.43	0.2	6	97.73	96.88
plugging*	3.3	0.98	6	90.91	78.13
pointing*	2.33	0.1	5	100	96.88
poking	2.87				
polishing*	3.97	1.43	6	59.09	40.63
popping	2.1				
posting*	2.57	0.2	6	97.73	96.88
pouring*	2.76	0.57	7	93.18	87.5
praying*	2.67	0.35	5	97.73	87.5
pressing	2.6				
pulling*	2.3	0.79	6	97.73	68.75
punching*	2.93	1.07	3	86.36	75
pushing*	2.2	0.1	6	100	96.88
racing*	2.53	0.8	1	77.27	87.5
raking	3.8				
reaching*	2.77	0.34	5	97.73	90.63
reading*	2.1	0	5	100	100
rearing	4.1				
receiving	4.13				
refusing	4.37				
removing	4.03				
resuscitating	6.1				
riding*	2.43	0.38	5	95.45	93.75
ringing*	2.57	0.24	6	97.73	93.75
ripping	2.79				
rolling*	2.33	2.21	6	70.45	34.38
roping	2.79				
rowing*	3.33	0.18	5	97.73	96.88
rubbing*	2.3	2.6	7	43.18	40.63
running*	1.7	0.8	5	88.64	84.38
sailing*	2.93	0.2	2	97.73	96.88
saluting*	4.5	0.52	5	81.82	96.88
sawing*	2.67	0.45	6	95.45	90.63
scratching*	2.73	0.2	5	97.73	96.88
screwing*	3.4	0.77	6	95.45	78.13
scrubbing*	3.47	2.05	5	45.45	62.5
separate	4.33				
sewing	3.1				
shaking*	2.97	0.81	8	72.73	87.5
sharing	2.63				
sharpening	3.55				
shearing	4.73				
shooting*	3.07	1.16	5	97.73	50
shoving	3.47				
shredding	4.2				
shrugging	4.3				
shuffling*	4.1	1.61	7	75	56.25
signing	3.4				
singing*	2	0.1	5	97.73	100
sitting*	1.43	0.4	5	97.73	87.5
skating*	3.38	0.79	5	90.91	81.25

skiing*	3.53	0.2	5	100	93.75
slapping*	2.6	1.6	3	84.09	53.13
sledging*	4.13	2.12	5	63.64	25
sleeping*	1.37	0	5	100	100
slicing	3.27				
sliding	2.4				
slouching	4.53				
smearing	4.43				
smelling*	2.1	0.4	6	86.36	100
smiling*	1.4	0.18	5	100	93.75
smoking*	3.37	0.1	7	97.73	100
snapping	2.9				
sneezing*	2.3	1.42	5	63.64	53.13
speaking	2.07				
spilling	2.67				
spinning	2.83				
spitting	2.77				
spraying*	3.63	0.94	7	100	65.63
spreading	3.37				
sprinkling	3.87				
squatting	4.57				
squeezing*	3.13	0.69	6	86.36	93.75
squinting	4.6				
stacking	3.97				
staining	3.67				
standing*	2	0.1	5	97.73	100
sticking	2.33				
stirring*	2.87	0	7	100	100
straddling	5.07				
straightening	4.17				
stretching	3.2				
surfing*	4.67	0.88	5	100	65.63
sweeping*	3.21	1.73	7	63.64	53.13
swimming*	2.37	0	5	100	100
swinging*	1.97	0.18	5	97.73	96.88
switching	3.37				
threading	3.63				
throwing	2.37				
tickling*	2.03	0.62	3	93.18	84.38
tieing	2.9				
tiptoeing	2.48				
toasting	2.21				
tracing	3.97				
trading	4.45				
trimming	4.2				
tucking*	3	2.52	5	54.55	46.88
turning*	2.57	1.57	6	77.27	68.75
twirling*	3.53	2.44	7	50	31.25
twisting*	3.4	1.4	6	77.27	65.63
typing*	3.93	1.08	5	97.73	56.25
unlocking	3.7				
walking*	1.7	0.18	5	97.73	96.88
washing*	1.87	0.18	5	97.73	96.88

watching*	2.5	0.93	5	84.09	71.88
watering*	1.6	1.3	6	81.82	62.5
waving*	1.4	0.44	5	97.73	87.5
weaving	4.45				
weighing*	2.87	0.54	5	93.18	87.5
whispering*	2.87	0.55	5	95.45	87.5
whittling	5.97				
winding	2.27				
winking*	3.1	0.1	5	100	96.88
wiping	2.63				
wrapping	3.1				
wrestling*	3.97	0.96	3	79.55	90.63
wrinkling	4				
writing	2.43				
yawning	2.37				
yelling□	3.1				

Prompts used in Expts 1a and 1b

Prompt 1: What are the animals doing?

Prompt 2: What is this object doing?

Prompt 3: What is the person doing to the other person?

Prompt 4: What are the people doing?

Prompt 5: What is this person doing?

Prompt 6: What is the person doing with this object?

Prompt 7: What is the person doing to this object?

Prompt 8: What is the person doing with the other person?

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Table 1

Mean Naming Latencies (in Milliseconds) and Error Rates for Young Adults (Experiment 1a) and Old Adults (Experiment 1b)

	Expt 1a Young Adults	Expt 1b Older Adults
Mean RT	1277	1525
(SD)	(310)	(418)
Naming errors (%)	12.2	21.8
Equipment failures (%)	0.5	1.1

Table 2
Correlations among the Key Predictor Variables Experiments 1a & 1b

	aoa	fam	vis	ima	let	syl	pho	wf-ing	wf	LF
fam	-.38									
vis	.25	-.45								
ima	.13	.16	.06							
let	.36	-.13	-.16	.17						
syl	.42	-.12	.07	.18	.68					
pho	.46	-.19	-.02	.08	.60	.53				
wf-ing	-.63	.24	-.28	-.37	-.25	-.30	-.39			
wf	-.54	.22	-.27	-.41	-.20	-.30	-.33	.94		
lf	-.59	.26	-.35	-.45	-.20	-.28	-.34	.95	.94	
H	.48	-.13	.05	-.10	.25	.16	.28	-.39	-.33	-.30

Note. Familiarity–fam; Visual Complexity–vis; Image Agreement–ima; Length (letters)–let; Length (syllables)–syl; Length (phonemes)–pho; Frequency (*-ing* form)–wf-ing; Frequency (Word base)–wf; Frequency (Lemma)–lf; Overall H Statistic–H.

Table 3
Simple Correlations between Predictors and Dependent Measures for Experiments 1a and 1b

	Expt 1a Young Adults		Expt 1b Old Adults	
	RT	Error Rate	RT	Error Rate
AoA	.43	.36	.47	.46
Familiarity	-.13	.08	-.25	.08
Visual Complexity	.10	.01	.28	-.06
Image Agreement	-.10	.04	-.05	.05
No. of Letters	.20	-.28	.11	-.20
No. of Syllables	.17	-.15	.19	-.13
No. Of Phonemes	.14	-.28	.22	-.28
Frequency Log +1 Word *-ing*	-.22	.32	-.25	.39
Frequency Log +1 Word base	-.15	.27	-.22	.35
Frequency Log +1 Lemma	-.16	.24	-.21	.31
H Statistic†	.64		.61	

† The Young H Statistic was utilised for the analysis of Experiment 1a and the Old H Statistic was utilised for the analysis of Experiment 1b.

Table 4
Multiple Regression Analyses on Naming Latencies Experiments 1a & 1b

	Expt 1a Young Adults				Expt 1b Old Adults			
	□ Coeff	SE	t	p	□ Coeff	SE	t	p
AoA	.316	38.0	2.82	.006	.245	49.8	2.26	.03
Familiarity	.065	39.8	.71	.48	-.037	51.1	-.42	.68
Vis. comp.	.079	34.0	.92	.36	.226	43.4	2.76	.007
Image agree	-.075	57.5	-.85	.40	.060	75.5	.71	.48
No. syllables	-.002	58.8	.02	.98	.041	75.4	.51	.61
Frequency Log +1 Word *-ing*	.118	50.1	1.10	.28	.244	65.4	2.35	.02
H†	.53	41.9	6.36	<.0001	. 589	46.3	6.81	<.0001
Voicing	.001	57.7	.01	.99	.016	74.4	.18	.86
Frication	-.008	61.3	-.08	.93	-.004	78.5	-.04	.97

†The Young H Statistic was utilised for the analysis of Experiment 1a and the Old H Statistic was utilised for the analysis of Experiment 1b.

Table 5
Multiple Regression Analyses on Proportion of Errors Experiments 1a & 1b (N=110)

	Expt 1a Young Adults				Expt 1b Old Adults			
	Coeff	SE	t	p	Coeff	SE	t	p
AoA	-.245	2.06	-1.96	.05	-.353	2.64	-3.00	.003
Familiarity	-.081	2.28	-.75	.46	-.165	2.93	-1.61	.11
Vis. comp.	.089	1.99	.86	.39	.009	2.55	.09	.99
Image agree	.174	3.18	1.74	.08	.233	4.08	2.48	.02
No. Phonemes	-.104	1.59	-1.01	.32	-.062	2.04	-.64	.53
Frequency Log +1 Word-*ing*	.233	2.86	1.85	.07	.273	3.67	2.30	.02

Table 6
Mean Naming Latencies (in Milliseconds) and Error Rates for Young Adults (Experiment 2a) and Old Adults (Experiment 2b)

	Expt 2a Young Adults	Expt 2b Old Adults
Mean RT (SD)	429 (24)	523 (32)
Naming errors (%)	0.6	0.7
Equipment failures (%)	1.2	3.4

Table 7
Correlations among the Predictor Variables Experiments 2a & 2b (N=267)

	aoa	fam	let	syl	pho	wf-ing	wf	lf
fam	-.33							
let	.33	-.09						
syl	.52	-.07	.46					
pho	.54	-.08	.41	.66				
wf-ing	-.53	.28	-.16	-.25	-.28			
wf	-.48	.31	-.14	-.17	-.22	.87		
lf	-.52	.34	-.15	-.22	-.24	.91	.94	
imag	-.50	.26	-.10	-.23	-.17	.25	.18	.18

Note. Familiarity–fam; No. of Letters–let; No. of Syllables–syl; No. of Phonemes–pho; Frequency Log +1 Word *-ing* form–wf-ing; Frequency Log +1 Word base–wf; Frequency Log +1 Lemma–lf; Imageability-imag.

Table 8
Simple Correlations between Predictors and Naming Latency (N=267) in Experiment 2a (Young Adults) and Experiment 2b (Old Adults)

	Expt 2a Young Adults RT	Expt 2b Old Adults RT
AoA	.32	.32
Familiarity	-.14	-.19
No. of Letters	.21	.20
No. of Syllables	.25	.26
No. Of Phonemes	.28	.26
Frequency Log +1 Word-*ing*	-.23	-.18
Frequency Log +1 Word base	-.20	-.16
Frequency Log +1 Lemma	-.22	-.19
Imageability	-.10	-.13

Table 9
Multiple Regression Analysis on Naming Latency in Experiment 2a (Young Adults) and Experiment 2b (Old Adults)

	Expt 2a Young Adults				Expt 2b Old Adults			
	□ Coeff	SE	t	p	□ Coeff	SE	t	p
AoA	.208	2.00	2.39	.02	.242	2.56	2.92	.004
Imageability	.065	2.05	.96	.34	.079	2.62	1.24	.22
Familiarity	-.045	2.02	-.72	.47	-.088	2.59	-1.49	.14
Phonemes	.129	3.08	1.87	.06	.089	3.93	1.36	.17
Frequency Log +1 Word *-ing*	-.093	2.43	-1.35	.18	-.052	3.11	-.79	.43
Voicing	.167	3.55	2.25	.03	.385	4.54	5.48	.0001
Fricative	.191	3.64	2.59	.01	.102	4.65	1.46	.15